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THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

DECEMBER, 1952

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Metals Economy: Report of Advisory Committee

'Report of the Metals Economy Advisory Committee.' *Published by H.M.S.O.*, London, Sept. 11, 1952; 17 pp. Price 9d.

The Report records the work of the Committee appointed, in August, 1951, with the following terms of reference: 'To bring under review, in consultation with the various Government and industrial authorities concerned, ways of economizing in the use of scarce metals in the design, specification and the manufacturing process of metal goods for both rearmament and civil purposes, and to advise the Government how it can best assist in promoting such developments.'

The introductory section describes the general approach of the Committee to its work, and its method of obtaining and assessing the information available. This is followed by a review of metals-economy work in progress in industry, under Governmental aegis, and elsewhere, giving some examples typical of the problems which the respective organizations have studied, and some solutions attained.

In view of the work already in progress when the M.E.A. Committee was formed, principal attention was given to the following aspects, which were considered to merit particular attention:—

(*a*) Tungsten economy in high-speed steel.
(*b*) Nickel economy in steam-condenser tubes.
(*c*) Molybdenum economy in carbon-molybdenum steels for power stations.
(*d*) Copper economy by the substitution of aluminium for copper in cables.
(*e*) Nickel economy in plating by the development of alternative plating finishes.

Conclusions reached on these five subjects are briefly summarized.

It is pointed out that there has been a radical change in the position with regard to scarcity of metals since the Committee started its work. The critical shortages threatened in the middle of 1951 have been averted, although supplies of most metals are still short of requirements. Only in the cases of lead and zinc has the shortage entirely disappeared. Nickel, cobalt and copper are still giving cause for concern, and supplies of other metals are at present adequate to meet essential needs only because of the restrictions which are being maintained on their use.

It is recommended that the Government should emphasize, through its many contacts with industry, the continuing need for the most economical use of metals supplies, by the adoption of the best techniques; that Government Departments be urged to intensify work on economical use of metals; that Defence Departments should consider the possibility of further economies; that the Government should provide industry, at regular intervals, with as much information as is practicable on supplies and possible shortages; that the Metals Economy Advisory Committee should continue, its work being adapted, as conditions require, to making the fullest possible contribution to metals economy.

Glossary of Terms used in Welding and Cutting

BRIT. STANDARDS INSTN.: 'Glossary of Terms (with Symbols) Relating to the Welding and Cutting of Metals.' B.S. 499: 1952. Price 21/-.

This revised, and much enlarged, Standard is divided into the following sections: terms common to most types of welding; welding with pressure; fusion welding; brazing and bronze welding; testing; weld imperfections; scheme of symbols; cutting. It also includes the matter previously published in B.S. 499: Part 2, which deals with terms relating to imperfections in welds appropriate for radiographic examination. The publication is well illustrated throughout, with sketches, line drawings, reproductions of radiographs, etc.

NICKEL

Transformations in Nickel Oxide

M. FOËX: 'Property Anomalies Accompanying λ-Type Transformations of Nickel Oxide.' *Bull. Soc. Chimique de France*, 1952, pp. 373-9; *Chemical Abstracts*, 1952, vol. 46, Aug. 25, p. 7393.

Account of observations made in preparation of NiO by heating $Ni(NO_3)_2$ at various temperatures, for various times. The results are succinctly summarized in *Chemical Abstracts*, *loc. cit.*

Formation of Oxide Films on Nickel Foil

W. J. MOORE and J. K. LEE: 'Kinetics of the Formation of Oxide Films on Nickel Foil.' *Trans. Faraday Soc.*, 1952, vol. 48, Oct., pp. 916-20.

The paper reports experiments on two lots of nickel foil, one made from carbonyl nickel, the other from a special electrolytic grade.

The rate of growth of the layer of nickel oxide on these specimens was studied from 400° to 900°C., at 10 cm. oxygen pressure.

Metals Economy: Report of Advisory Committee

See abstract on this page.

Nickel-containing Materials in Chemical Engineering: Annual Review

See abstract on p. 286.

ELECTRODEPOSITION AND OTHER COATING METHODS

Bright Nickel- and Chromium-Plating of Small Recessed Articles

F. SPICER: 'Bright Nickel and Chrome Plating.' *Industrial Finishing*, 1952, vol. 5, Oct., pp. 192-4.

The writer describes methods which he has used with success for plating of articles having deeply recessed portions, e.g., ash trays, spoons, egg cups, wristwatch cases, etc. Details of procedure are given with regard to plating of watch cases, as presenting particularly difficult problems.

Nickel Plating by Chemical Reduction

R. A. POWERS and N. HACKERMAN: 'Nickel Plating by Chemical Reduction. I. Effect of the Basis Metal.' *Jnl. Physical Chemistry*, 1952, vol. 56, Feb., pp. 187-8.

In attempting to extend to non-metallic surfaces the 'electroless' plating method described by BRENNER and RIDDELL (*Jnl. Res. Nat. Bur. Standards*, 1947, vol. 39, p. 385), additional information on the process occurring at metallic surfaces was desirable. Brenner and Riddell had concluded that the reduction of the nickel ion by sodium hypophosphite took place on only a limited number of metals, indicating that the metal itself was an integral component (possibly catalytic), or that growth of a nickel lattice required as a basis a similar, possibly a particular, surface configuration.

If any of these factors were found to be essential in the deposition process the use of glass or other non-metallic surfaces would be impossible in this type of plating. The study reported in the present paper was made to establish the significance of the factors mentioned. Following preliminary experiments with block steel, deposition of thin nickel films on ultra-thin evaporated metal films was investigated, using nickel, iron, gold, copper, and platinum films, on glass, as base. The results show that surface configuration of the supporting substance is not of major importance in inducing deposition of nickel by chemical reduction, either through a similarity to the nickel lattice or through catalytic activity due to surface geometry.

Metals Economy: Report of Advisory Committee

See abstract on p. 276.

Filtering of Nickel Baths used for Flashing Prior to Enamelling

'How to Save Nickel in an Enamel Plant by Lengthening Bath Life.' *Ceramic Industry*, 1952, vol. 58, Mar., p. 61.

Nickel-flashing baths which have become contaminated by iron may be cleared by transforming the colloidal iron present into particles of filterable form. The addition of an oxidizing agent to the solution is the basis of the method. Small amounts of such media as potassium or sodium permanganate or persulphate, hydrogen peroxide, or potassium chromate are stated to be suitable. Hydrogen peroxide is to be recommended if it is particularly desired not to build up the sodium content of the bath, but sodium persulphate is also reported as giving good results. The method has the advantage that it can be operated during production, without shut-down for precipitation and filtering.

In the April issue of the same journal (p. 111) a drawing is given of the essential components of a filter arrangement suitable for a 1500-gall. tank, utilizing the method described. A letter from an enamelling firm which has tried out the method is also reproduced: it records successful use of potassium permanganate as the treatment medium, but states that for general use hydrogen peroxide will be employed.

Plating of Nickel-Cobalt-Iron Alloys for Glass-to-Metal Seals

J. C. TURNBULL: 'A High-Conductivity Glass-to-Metal Seal.' *R.C.A. Review*, 1952, vol. 13, Sept., pp. 291-9.

Kovar*-to-glass seals, which, on account of their good resistance to mechanical and thermal shock, and their ease of fabrication, are widely used in construction of power tubes, may at high frequencies be subject to severe heating, as a result of electrical losses in the glassed-metal surfaces. Seal heating may be reduced by coating the Kovar with a metal of higher conductivity, such plating being carried out before the seal is made. This paper describes methods for plating Kovar with copper+chromium, and discusses the properties of the plated seals. A relatively thick undercoat of copper is used, to ensure conductivity, and a thin outer coating of chromium, to provide a surface to which glass can readily be sealed. The effect of variation in thickness of copper and chromium layers, on residual strain in the seals, and on seal heating, is considered. For operation at frequencies of 100 to 120 megacycles, Kovar seals plated by this method are found to have a current-carrying capacity more than 5 times that of unplated Kovar, and the conductivity is increased by a factor of 25.

Stress-Corrosion Tests on Plated Bronze

See abstract on p. 286.

NON-FERROUS ALLOYS

Lattice Vacancies and Porosity in Nickel-Copper Alloys

E. C. ELLWOOD: 'Lattice Vacancies and Porosity in Copper-Nickel Alloys.' *Nature*, 1952, vol. 170, Oct. 4, pp. 580-1.

It has previously been shown by the author that in aluminium-zinc and gold-nickel alloys lattice vacancies occur in solid solutions when Brillouin zones are filled (see *Nickel Bulletin*, 1952, vol. 25, Nos. 8-9, p. 204). The present note reports experiments on copper-nickel alloys, indicating that lattice vacancies

* Nickel-cobalt-iron alloy

occur also in this series, particularly when less than 80 per cent. of nickel is present. Alloys containing various percentages of the two elements were melted and solidified in vacuo, annealed in a vacuum for seven days at 900°C., reduced 50 per cent. in thickness by hammering at room temperature, and finally annealed in vacuo at temperatures ranging from 700° to 970°C., for periods up to 4,175 hours. Density measurements made at intervals showed that the alloys grew progressively: the amount of growth was dependent on the temperature of annealing and the number of lattice vacancies. A photomicrograph illustrates the microstructure of an alloy containing 80 per cent. of copper after annealing for 4,175 hours at 900°C., during which treatment its volume increased by 4·5 per cent. Considerable microporosity is observed, almost all of it occurring in the crystal boundaries, with very little at twin boundaries or in the crystals. Alloys containing less than 20 per cent. of copper (in which there are comparatively few lattice vacancies) show less than 0·1 per cent. growth under similar conditions.

Constitution of Nickel-Iron-Molybdenum and Nickel-Cobalt-Molybdenum Alloys

D. K. DAS, S. P. RIDEOUT and P. A. BECK: 'Intermediate Phases in the Mo-Fe-Co, Mo-Fe-Ni and Mo-Ni-Co Ternary Systems.' *Jnl. of Metals*, 1952, vol. 4, Oct., *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1071-5.

In a previous paper isothermal phase-diagram sections at 1200°C. were given for the chromium-cobalt-nickel, chromium-cobalt-iron, chromium-cobalt-molybdenum and chromium-nickel-molybdenum systems, in which the σ-phase formed narrow, elongated solid-solution fields (see abstract in *Nickel Bulletin*, 1951, vol. 24, No. 12, pp. 263-4). The present investigation is concerned with the 1200°C. isothermal sections of three additional ternary systems which are of interest in connexion with high-temperature alloys. A prominent feature of these systems is the presence of narrow, elongated μ phase fields.

The following introductory notes are given to form a background for the conclusions drawn from the present investigation, and to correlate results of cognate researches:

'The crystal structure of the phase designation μ (in both this and the earlier investigation) was determined by ARNFELT and WESTGREN. For the (Co, W) μ phase, named by them Co_7W_6 (and also frequently designated as δ), these authors found that the crystal system is hexagonal-rhombohedral and the space group is $D^5_{3d}-R3_m$. WESTGREN and MAGNELI later found that isomorphous phases exist in the Fe-W and the Fe-Mo systems (these phases are referred to as ζ and ε, respectively). HENGLEIN and KOHSOK stated that the phase described by them as Co_7Mo_6 (otherwise frequently designated as ε) is also isomorphous with the above three.

'The Co-Fe-Mo system was investigated at 1300°C. by KÖSTER and TONN, who found a continuous series of solid solutions between (Co, Mo) μ and (Fe, Mo) μ. KÖSTER also indicated similar uninterrupted solid solutions in the Ni-Fe-Mo system. However, since the Ni-Mo binary system does not have a phase isomorphous with μ, KÖSTER's diagram is expected to be erroneous. No data appear to be available in the literature concerning the Co-Ni-Mo system.

'The face-centred cubic (austenitic) solid solutions of iron, nickel, and cobalt, which are quite extensive in all three systems at 1200°C., are here designated as the α phase. The body-centred cubic (ferritic) solid solutions, based on iron, are designated in this report as the ε phase, in conformity with the nomenclature used in the authors' previous report.'

The conclusions drawn from the examination of the molybdenum-iron-cobalt, molybdenum-iron-nickel and molybdenum-nickel-cobalt systems investigated in the present research are as follows:—

1. In these systems at 1200°C. the μ phase forms narrow, elongated ternary solid-solution fields. In the first-named the μ field extends all the way across the ternary diagram; in the other two systems it reaches only approximately half-way across.
2. If the electron vacancy numbers assigned to molybdenum, iron, cobalt, and nickel are 4·66, 2·2, 1·71 and 1·6, respectively, the elongated μ-phase fields in the above ternary systems correspond quite well to a constant electron vacancy range of about 2·95-3·25.
3. The alloying behaviour of the μ-phase is entirely analogous to that previously found for the σ phase. It is quite likely that there are still other 'electron vacancy phases' of this type among the intermediate phases in alloys of the transition elements. The study of ternary phase diagrams is highly effective in disclosing such properties.

Nickel-Manganese-Antimony Alloys

L. CASTELLIZ : 'A Ferromagnetic Phase in the Nickel-Manganese-Antimony System.' *Österreichische Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse, Sitzungsberichte, Abt. IIb., Chemie*, 1951, vol. 160, pp. 1059-85.

Report of examination (involving X-ray analysis, determination of magnetic susceptibility, and measurements of Curie temperature) of various alloys within the concentration ratios nickel : manganese : antimony 2:1:1 and 1:1:1 and between nickel-manganese-antimony 1:1:1 and the binary limits 1:1. For summary of observations made see *British Abstracts*, B. I., 1952, June, p. 865.

Influence of Small Amounts of Other Elements on Hardness of Nickel

M. A. MEYER: 'The Hardness of Primary Substitutional Nickel Alloys.' *Bull. Inst. Metals*, 1952, vol. 1, Oct., pp. 121-3.

Account of experiments to determine the effect of various alloying elements (in amounts up to 5 at. per cent.) on the Vickers and Meyer hardnesses of nickel. Data on nickel-tin, -antimony, -molybdenum, -silicon, -manganese, -aluminium, -chromium, -iron, -copper, -cobalt, and -tungsten alloys. The hardness of

nickel was raised by addition of all the elements studied, and, except in the case of tin, silicon and antimony, increase in hardness was a linear function of atomic concentration of the second element. The gradient of the hardness-concentration curve for the nickel-silicon alloys increased, whereas in alloys containing tin or antimony the gradient decreased with increasing concentration of the alloying metal. Similar curves were obtained at $-183°$ and $+300°$C.

Hardness of the alloy, H_{alloy}, decreased with rise in temperature, but increase in hardness due to alloying (i.e., $H_{alloy}-H_{nickel}$) was approximately independent of temperature within the range studied. The index *n* (occurring in Meyer's law), which may be regarded as a measure of the ductility of the alloy, decreased with increasing concentration of the alloying element. This was particularly marked in alloys containing elements which have a considerable hardening effect on nickel.

Metals Economy: Report of Advisory Committee

See abstract on p. 276.

Properties of 90-10 Cupro-Nickel containing Iron

W. C. STEWART and F. L. LAQUE: 'Corrosion-Resisting Characteristics of Iron-Modified 90-10 Cupro-Nickel Alloy.'*

Reprint from *Corrosion*, 1952, vol. 8, Aug., pp. 259-77; issued by International Nickel Co., Inc.

For abstract see *Nickel Bulletin*, 1952, vol. 25, No. 10, pp. 247-8.

Oxidation Characteristics of Alloys: Nickel-Platinum and Nickel-Copper Alloys

See abstract on p. 283.

Nickel-Aluminium Bronze Castings: Production and Properties

V. DE PIERRE and R. C. WYNNE: 'Production of Aluminium-Nickel Bronze Sand Castings.'* Reprint of article from *Foundry*, July, 1952; issued by International Nickel Co., Inc.; 6 pp.

For abstract see *Nickel Bulletin*, 1952, vol. 25, No. 10, pp. 234-5.

CAST IRON

Effect of Composition and Section Size on Properties of S.G. Iron

D. J. REESE, F. B. ROTE and G. A. CONGER: 'Effect of Chemistry and Section Size on Properties of Ductile Iron.'* *Reprint from Quarterly Trans., Soc. Automotive Engineers*, 1952, vol. 6, July, pp. 385-94. Issued by International Nickel Co., Inc., 1952.

The paper reports an investigation of the effects of variation in carbon, silicon and phosphorus contents, on the structure and properties of S.G. iron cast into sections ranging from ½-in. to 6-in. thick, and studied in both the as-cast and the annealed conditions. In some cases the castings were also tested after being subjected to special forms of heat-treatment, e.g., quenching-and-tempering, isothermal annealing, etc. Results are shown in a comprehensive series of tables and graphs, demonstrating the wide range of properties which may be developed in S.G. irons (both in heavy and light sections) by modifications of composition and heat-treatment.

It is concluded that, in general, control of composition should be based on silicon. Variation in carbon content exerts little influence on properties: phosphorus is detrimental, and should be kept as low as possible. Curves and formulae are presented relating silicon content and section thickness with properties. It is concluded that in as-cast irons maximum strength, in all sections, is secured at 1·5-2·5 per cent. silicon. Optimum mechanical properties are produced by quenching and tempering, or by isothermal transformation at 590°-650°C. In castings annealed to produce maximum ductility, tensile and yield properties are directly related to silicon content: quantitative relationships are indicated for parts of ½-in. and 6-in. section.

*Copies of this publication will shortly be available.

Properties of Low- and High-Alloy S.G. Iron

J. L. GOHEEN: 'Designing with Ductile Iron.' *Machine Design*, 1952, vol. 24, June, pp. 161-6.

This paper is based on experience of the American Brake Shoe Company, which is already producing S.G. iron at two of its plants, and is equipping a third foundry solely for this purpose. Three grades of S.G. iron are being made (under the designation 'Ductalloy'), two which are covered by the A.S.T.M. specification (for details see *Nickel Bulletin*, 1952, vol. 25, No. 4, p. 105), and an austenitic type. Mechanical and physical properties of all three grades are tabulated in the paper, and some comparison is made with the corresponding characteristics of cast steels, malleable cast iron, grey cast irons, and some non-ferrous alloys used in engineering applications.

Applications of S.G. Iron

'Ductile Iron Makes Good Abroad.' *Nickel Topics*, 1952, vol. 5, No. 6, p. 5.

Illustrations of, and brief notes on, some of the S.G. iron castings exhibited, by foundries in Europe, at the International Foundry Congress and Exhibition held at Atlantic City in May 1952.

Gas-Cutting of S.G. Iron

'Oxygen-Cutting of Nodular-Graphite Cast Iron.' *Iron and Coal Trades Rev.*, 1952, vol. 165, Aug. 8, p. 326.

It has been found that, unlike grey cast iron, S.G. iron may be gas-cut almost as easily as mild steel. A standard oxygen-cutting machine may be used, and the cut surface is similar to that of mild steel. It is claimed that in cutting S.G. iron the amount of oxygen gas and fuel gas required is only about 1/10th of that necessary for an exactly similar cutting operation

on grey cast iron, and the work is done some six times as quickly. The differences are attributed solely to the difference in the form of graphite in the two irons, since in both cases the matrix structures of the materials on which the tests were made were fully pearlitic. Annealed and as-cast S.G. iron cut equally easily.

Like other cast irons, S.G. iron surface-hardens on cutting, but the effect can be neutralized by flame-tempering after cutting. Cracking can be prevented by suitable pre-heating. The suitability of S.G. iron for gas-cutting should prove particularly useful in removal of risers from large castings.

Analysis of Cast Iron

W. WESTWOOD and R. PRESSER: 'Determination of Some Residual Elements which Produce Harmful Effects in Magnesium-Treated Nodular Cast Iron.' *Brit. Cast Iron Research Assocn., Jnl. of Research and Development*, 1952, vol. 4, Aug., pp. 369-86; Res. Rept. 340.

In recent papers (see *Nickel Bulletin*, 1952, vol. 25, Nos. 6 and 8-9, pp. 152-3 and 208) MORROGH described the deleterious influence of certain elements on the response of cast iron to magnesium treatment. In the present report the authors describe chemical methods for determination of the following interfering elements, in appropriate ranges: aluminium, antimony, arsenic, bismuth, lead, tin, titanium.

NICKEL-IRON ALLOYS

Order-Disorder Transformation in Nickel-Iron Alloys: Influence of Third Element

E. JOSSO: 'Order-Disorder Transformation in Ternary Alloys.' *Revue de Métallurgie*, 1952, vol. 49, Oct., pp. 727-32.

Study of (1) binary alloys containing 68-80 per cent. of nickel; (2) alloys containing 64-76 per cent. of nickel, 5 per cent. of copper, balance iron; (3) alloys containing 70-78 per cent. nickel, 4 per cent. of molybdenum, balance iron. Alloys of the above types were prepared from powders of high purity, and their behaviour was compared with that of similar materials made by melting, casting and forging. Dilatometric study was made, and electrical resistivity was determined in relation to the degree of ordering.

The results indicate that although additions of copper or molybdenum do not entirely suppress the tendency towards ordering in the nickel-iron alloys, the presence of these elements does to some extent modify the phenomenon. Both have the effect of lowering the critical temperature of the transformation (the influence of copper being stronger than that of molybdenum in this respect). In the copper-containing alloys, as in the binary nickel-irons, resistivity falls when ordering takes place, whereas the molybdenum-modified nickel-irons show a higher resistivity in the ordered than in the disordered condition. With regard to dilatometric behaviour also, the copper-containing alloys behave more like the corresponding binary nickel-iron alloys than do the molybdenum-containing type. The work appears to be closely related to that reported in *Jnl. de Physique et le Radium*, 1951, vol. 12, pp. 399-401; see *Nickel Bulletin*, 1952, vol. 25, No. 2, pp. 44-5.

The author also studied order-disorder phenomena in iron-cobalt alloys.

Constitution of Nickel-Iron-Molybdenum Alloys

See abstract on p. 278.

Plating of Nickel-Cobalt-Iron Alloys for Glass-to-Metal Seals

See abstract on p. 277.

Nickel-Zinc Ferrites

K. F. NIESSEN: 'Spontaneous Magnetization of Nickel-Zinc Ferrite as a Function of the Nickel: Zinc Ratio.' *Physica*, 1952, vol. 18, Nos. 6-7, June-July, pp. 449-68.

CONSTRUCTIONAL STEELS

Transformation Characteristics of Nickel-Alloy Steels

MOND NICKEL CO., LTD.: 'Transformation Characteristics of Nickel Steels.'* *Publn. 568* (revised and amplified version of *Publn. 428*): see abstract in *Nickel Bulletin*, 1951, vol. 24, No. 6, p. 138.

This book, which is intended solely as a reference manual for metallurgists, contains isothermal transformation diagrams and end-quench hardenability curves for a comprehensive selection of the more important nickel-alloy steels. The information given is based on experimental determinations in the laboratory of The Mond Nickel Company, Ltd., supported by information culled from the literature, which is represented by a *bibliography* of 51 references.

Rare-Earth Additions to Steels

G. A. LILLIEQVIST and C. G. MICKELSON: 'Properties of Cast Steels Improved with Rare Earth Element Additions.'
Jnl. of Metals, 1952, vol. 4, Oct., pp. 1024-31.

Report of a systematic investigation of the influence, on the properties of typical plain and low-alloy (manganese) cast steels, of additions of LanCerAmp, the rare-earth addition alloy produced by American Metallurgical Products Company. Individual sections of the report cover the effects of LanCerAmp on mechanical properties, temper-brittleness, inclusions and microstructure, fluidity, susceptibility to hot-tearing, removal of sulphur, hardenability, porosity, weldability, and feeding characteristics. For further details of the nature and properties of LanCerAmp, see *Iron Age*, 1952, vol. 169, Apr. 24, pp. 129-34; May 1, pp. 140-3: abstract in *Nickel Bulletin*, 1952, vol. 25, No. 7, pp. 176-7.

* *We shall be pleased to supply a free copy of this publication.*

Non-Magnetic Nickel-containing Steels and Cast Irons

C. T. EAKIN: 'Non-Magnetic Steels.'
Electrical Manufacturing, 1952, vol. 50, July, pp. 108-12, 268, 270, 272.

A review of the composition and properties of non-magnetic steels and cast irons of interest to the electrical engineer. Following a brief consideration of the basic characteristics of non-magnetic steels, specific materials having such characteristics are reviewed in four groups: chromium-nickel (austenitic) steels, manganese-nickel steels, high-manganese steels, and high-alloy nickel-containing cast irons. Data are tabulated on mechanical and physical properties, and magnetic and electrical qualities.

Low-Temperature Mechanical Properties of Plain and Alloy Steels

J. S. BRISTOW: 'Low-Temperature Steels: Properties and Recommendations.' *Iron and Steel*, 1952, vol. 25, Oct., pp. 447-51.

A well documented discussion, covering the sub-zero properties of a wide range of steels, the significance of the notch-impact test as a criterion of low-temperature toughness, the effect of fatigue on transition from ductile to brittle fracture, and the factors affecting retention of toughness. In discussing the low-temperature characteristics of alloy steels, particular attention is directed to the value of nickel as a toughening element. In the lower-alloy groups nickel is the only metal which has been found to have pronouncedly beneficial influence in this respect, but its inclusion is not alone sufficient to ensure satisfactory sub-zero toughness. Other factors, such as carbon content, grain size, deoxidation, tempering temperature, etc., must be taken into account. Graphs showing impact values down to −175°C. are shown for steels containing 2·0, 3·5, 5·0, 8·5 and 13 per cent. of nickel.

The outstandingly satisfactory behaviour of austenitic chromium-nickel steels is emphasized, with warning as to avoidance of borderline compositions in which martensite would be liable to form on prolonged exposure to low temperatures.

The paper is supported by a *bibliography* of 23 references.

Atmospheric Corrosion-Resistance of Low-Alloy Nickel-containing Steels

See abstract on p. 286.

Sulphide Stress-Corrosion: N.A.C.E. Symposium

See abstract on p. 284.

Standard Methods for Analysis of Iron and Steel

BRIT. STANDARDS INSTN.: 'Methods for the Analysis of Iron and Steel. Part 26. Molybdenum in Low-Alloy Steels containing up to 0·5 per cent. Tungsten.' *B.S.* 1121: *Part* 26: 1952.

Molybdenum is precipitated from a hydrochloric acid solution of the sample with alpha-benzoinoxime. The precipitate is re-dissolved, and molybdenum, after conversion to thiomolybdate, is separated as sulphide from a solution in which the precipitation of tungsten is prevented by the presence of tartrate ions. The sulphide precipitate is ignited and weighed as molybdic oxide. Full details of equipment and procedure are given. The range is 0·02-2 per cent. molybdenum.

Polarographic Determination of Titanium in Nickel-containing Materials

See abstract on p. 284.

HEAT- AND CORROSION-RESISTING ALLOYS

Sigma-Phase Embrittlement in 25-20 Chromium-Nickel Steels

J. I. MORLEY and H. W. KIRKBY: 'Sigma-Phase Embrittlement in 25 Cr–20 Ni Heat-Resisting Steels.' *Jnl. Iron and Steel Inst.*, 1952, vol. 172, Oct., pp. 129-42.

This paper, based on the results of numerous individual investigations carried out over a long period, deals mainly with σ-phase formation in 25-20 bar steel, and the influence of such change of structure on mechanical properties of the steel. Particular attention is given to the effect of variable grain size (arising from difference in annealing temperatures), on the distribution of the constituents, on their rates of precipitation, and on the tensile and impact properties of the steels after complete precipitation of the carbide and σ phases. Both microscopic and X-ray procedures were used as aids to detection of σ in solid specimens and in chemically extracted residues. Tensile and Izod-impact tests were carried out on a selection of the steels, a few of which were commercial bar stock, the remainder being ¾-in. diameter bars produced from 30-lb. induction-furnace melts.

From the results of the individual series of tests, which are presented in considerable detail and with many photomicrographs and other illustrations, the following main conclusions are drawn:—

'A typical bar steel containing carbon 0·10, silicon 1·50, chromium 24, nickel 20, per cent., is fully austenitic at 1150°C., but will precipitate chromium carbides between 1100° and about 925°C., and chromium carbides plus σ if heated for long periods at lower temperatures. The σ in this steel has been found to contain chromium 42, nickel 10, silicon 3, per cent., remainder iron. Because considerable diffusion of chromium and nickel has to occur, long periods of heating are required for σ to precipitate from the austenite.' (Typical temperatures and periods of heating are quoted.) 'This behaviour contrasts with that of some partially ferritic 18-8-Mo-Ti steels, where the higher concentrations of chromium and molybdenum in the ferrite than in the austenite at the annealing temperature may allow σ to precipitate during air-cooling of plate and bar.

'σ precipitates on relatively few nuclei, mainly in the grain boundaries of fine-grained 25-20 steels heated at about 800°C. There is little hardening, and at least 20 per cent. elongation may be shown by steels containing 15 per cent. by volume of σ. In tensile tests

the σ particles fracture, but the cracks do not readily propagate. Izod impact resistance at room temperature is much reduced.

'The amount of σ at any temperature can vary widely with small differences in composition of the steel . . . Chromium, silicon, and, to a lesser extent, manganese, are σ-promoting elements: σ-inhibiting elements are carbon, nitrogen, and nickel, the former because of their ability to reduce the effective chromium content. Nickel has only a mild effect. Carbide-stabilizing elements, *e.g.*, titanium and niobium, reduce the σ-inhibiting effect of carbon. Within the limits of composition investigated, no single variation seems capable of eliminating σ in the range 700°-850°C., though the temperature range over which it is stable is modified. By combining two or more composition changes σ can be completely suppressed at 700°C. without appreciably modifying the chromium content.

'The extent of room-temperature embrittlement is clearly related to the amount of σ present, although the relation depends on grain size . . . The greater embrittlement of the coarser-grained steels for a given σ content appears to be explained mainly by the semi-continuous grain-boundary film of precipitated σ, which is not seen in fine-grained steels . . . The influence of carbide precipitation is also more pronounced in coarse-grained steels, but its additional embrittling effect is limited.

'Hot ductility of steels containing σ is somewhat better than the room-temperature ductility.

'The rate of σ precipitation depends on composition, temperature, and prior mechanical and heat-treatment.'

(Quantitative data supporting all the above conclusions are recorded.)

Metastable phases occurring in 25-20 chromium-nickel steels include chromium carbide and ferrite: the nature of both phases is discussed.

The results reported by the authors indicate that if the choice of a steel for a particular application depends on consideration of σ embrittlement and oxidation-resistance, it may not be necessary to use a completely σ-free steel. Fine-grained steels (0·03 mm. grains) are capable of giving 30 per cent. elongation in the tensile test, even when 10 per cent. of σ is present, although the impact value is very low. Such an elongation value is consistent with the very satisfactory service record shown by wrought 25-20 steels. The same amount of σ in a coarse-grained steel (*e.g.*, 0·15 mm. grains) can, however, cause serious embrittlement. In such steels only about 2 per cent. of σ can be tolerated if room-temperature ductility must be preserved. The data presented facilitate the choice of steels on this basis.

Inter-Relation of Hot-Hardness and Creep in Austenitic Steels

F. GAROFALO, P. R. MALENOCK and G. V. SMITH: 'Hardness of Various Steels at Elevated Temperatures.' *Amer. Soc. Metals, Preprint* 18, Oct., 1952; 18 pp.

Following a condensed review of methods which have been used for determination of hot-hardness (with particular reference to the potential value of static, as compared with dynamic tests), the authors describe apparatus in which both specimen and (sapphire) indenter are heated to the desired temperature in a virtually inert atmosphere, and the hardness is determined by means of automatic application of a deadweight load onto the indenter while it is in contact with the specimen. When the loading cycle, of fixed duration, is complete the load is automatically removed. By rotating the cylindrical specimen after each loading and unloading cycle, a number of impressions up to 18 can be made at temperature, while maintaining the inert atmosphere. The assembly is then cooled to room temperature, the specimen is removed, and hardness is measured as in the standard Vickers test. A full description is given of equipment and procedure, illustrated by a photograph and a schematic diagram. It is noted as a further point of interest that it is possible to maintain a specimen at elevated temperature for an extended period, under constant conditions, taking measurements of hardness at intervals.

Determinations of hot-hardness made with this apparatus are reported, covering various grades of austenitic nickel-chromium and nickel-chromium-molybdenum steel, a selection of representative carbon steels, some aluminium-silicon steels, and a steel containing chromium 8, molybdenum 1, per cent.

Initial tests of hardness at room temperature indicated that method of preparation of the specimen, and duration of loading, have an appreciable effect on hardness values obtained: the effect of these variables is discussed. In the elevated-temperature tests hardness of the austenitic steels was tested at 75°, 1100°, 1300° and 1500°F. (23·8°, 595°, 705° and 815°C.). The hardness of an 18-8-Ti steel was compared with that of the aluminium-silicon and chromium-molybdenum grades at various temperatures within the range 75°-1500°F. (23·8°-815°C.), and the carbon steels were tested at 75° and 850°F. (23·8° and 455°C.). Comparison between the hot-hardness values and the creep strength of the steels, on the basis of stress-to-rupture in 1, 100 or 1,000 hours (graphically illustrated in the paper), indicates a definite relationship between the hardness and creep strength. Scatter of experimental values is least for 1-hour rupture and greatest for the 1,000-hour rupture. Some relation was also found between hot-hardness and stress causing a creep rate of 1 per cent. per 10,000 hours. A linear relationship was found between hardness and tensile strength at temperatures up to 1500°F. (815°C.). In all cases the relationships observed between hardness and other properties appear to be independent of structure and temperature of test, within the range covered.

Designing with Corrosion- and Heat-Resisting Alloy Castings

E. A. SCHOEFER: 'Design Considerations for Heat- and Corrosion-Resistant Castings.' *Machine Design*, 1952, vol. 24, Sept., pp. 148-54.

First of a series of articles discussing (1) general design features essential for successful use of nickel-chromium iron and other high-alloy castings, and (2) particulars of design required in specific cases.

This first instalment includes tables giving composition and properties typical of corrosion-resistant casting materials covered by A.S.T.M. A296-49T and of heat-resisting casting alloys to A.S.T.M. A297-49T.

Formation of Nitrides during Creep-Rupture Tests on Austenitic Steel

E. J. DULIS and G. V. SMITH: 'Formation of Nitrides from Atmospheric Exposure during Creep Rupture of 18% Cr, 8% Ni Steel.' *Jnl. of Metals*, 1952, vol. 4, Oct., *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1083-4; T.N. 127E.

Report of observations made on a 304L steel of the following composition: carbon 0·03, manganese 0·65, phosphorus 0·010, sulphur 0·019, silicon 0·54, chromium 19·50, nickel 12·02, nitrogen 0·031, aluminium 0·005, per cent. The sample was taken from a $\frac{1}{4}$-in. dia. creep-rupture specimen of annealed steel which had ruptured after 10,470 hours at 1500°F. (815°C.), under 2,000 p.s.i.

Nitrides were found distributed across the whole section of the sample, occurring both at the grain boundaries and within the grains. Chemical analysis showed 0·64 per cent. 'soluble' nitrogen (soluble in 1:1 hydrochloric acid:water) and 0·18 per cent. 'insoluble' nitrogen (insoluble in the hydrochloric acid solution but dissolved by fuming sulphuric acid). For identification of the precipitate by X-ray diffraction, the matrix in the surface layer of the specimen was dissolved by prolonged attack in an alcoholic solution of picric and hydrochloric acids. The observed X-ray diffraction lines showed the presence of Cr_2N and CrN. The mode of formation of the precipitates is discussed. Depletion of chromium in the austenite, by the formation of chromium nitride, unbalanced the matrix composition so that, on cooling from the test temperature, much or all of the austenite transformed to ferrite, presumably by a martensite-like reaction. Typical structures of the fractured creep-rupture specimen are illustrated.

Resistance of Nickel-containing Materials to Hydrogen Sulphide and Sulphur Dioxide

W. FARBER and D. M. EHRENBERG: 'High-Temperature Corrosion Rates of Several Metals with Hydrogen Sulfide and Sulfur Dioxide.' *Jnl. Electrochemical Soc.*, 1952, vol. 99, Oct., pp. 427-34.

Most of the investigations on effects of hydrogen sulphide, sulphur dioxide, and gaseous sulphur, on metals and alloys, have been of a qualitative nature: the main observations made during such studies are succinctly summarized as an introduction to this paper. The present authors used a method depending on the fact that corrosion rates can be determined from increase in electrical resistance of metal filaments. Mode of calculation is discussed, and an illustrated description is given of the apparatus used.

Corrosion rates were determined at temperatures above 1000°K. (727°C,) for copper, silver, Inconel, nickel, 18-8 chromium-nickel steel, iron, tungsten, molybdenum, and tantalum, and chromium plating on copper, in atmospheres of hydrogen sulphide in helium, carbon monoxide, or nitrogen, and in sulphur dioxide in helium. The results indicate that resistance of metals to sulphur-containing gases is determined by diluent gaseous atmosphere. In a reducing medium tungsten, molybdenum, tantalum and chromium are resistant to hydrogen sulphide: in presence of an oxidizing atmosphere, however, these metals are corroded quite rapidly. Nickel and its alloys proved resistant to sulphur dioxide, but corroded rapidly in hydrogen sulphide. Iron and copper were corroded rapidly by both sulphur dioxide and hydrogen sulphide. No evidence was found that carbon monoxide forms a carbonyl to any appreciable extent with any of the metals tested, in the 1000°-1500°K. (727°-1227°C.) range and at a pressure of 1 atmosphere. Corrosion of nickel by hydrogen sulphide was, however, slightly accelerated in the presence of carbon monoxide, in contrast to iron, where carbon monoxide as the diluent gas reduced corrosion.

Oxidation Characteristics of Alloys: Nickel-Platinum and Nickel-Copper Alloys

C. WAGNER: 'Theoretical Analysis of the Diffusion Processes Determining the Oxidation Rate of Alloys.' *Jnl. Electrochemical Soc.*, 1952, vol. 99, Oct., pp. 369-80.

In this paper the interplay of diffusion processes in metallic and oxide phases occurring during the oxidation of alloys is theoretically analyzed, for specified ideal conditions. The oxidation rate of alloys containing a noble metal (gold or platinum) and an oxidizable metal (nickel, copper or zinc) is calculated as a function of the composition of the alloy.

A considerable amount of the data presented relates to nickel-platinum alloys. Oxidation rate in this series, at 850° and 1100°C., is determined essentially by the diffusion of nickel to the alloy/NiO interface, if the mole fraction of nickel is less than 0·5. Observed rates of oxidation are in agreement with values calculated from diffusion data.

Alloys of which both constituents are oxidizable may form either a one-phase or a two-phase scale. A necessary, but not sufficient, condition for the formation of a scale consisting of only one oxide is stated. Some data on oxidation of copper-nickel and copper-zinc alloys are used to illustrate this portion of the discussion, and it is shown that their behaviour is essentially in accordance with theoretical considerations. It is also shown that two oxides may nucleate initially and continue to grow, even under conditions in which exclusive formation of the oxide of the less noble metal is a possible process. This phenomenon is illustrated by reference to observations on copper-aluminium alloys.

Rough-Machining of Austenitic Steel Castings

F. MENINGER: 'Centrifugally Cast Jet Engine Rings: How to Rough-Machine Them.' *Steel*, 1952, vol. 131, Oct. 6, pp. 78-9.

Short notes on procedure used at the plant of Cooper Alloy Foundry Company, Hillside, N.J., in rough-machining cast rings of high-chromium steel (A.I.S.I.

410), 23-12 chromium-nickel steel containing 2·5-3·5 per cent. tungsten, and molybdenum-containing 18-14 chromium-nickel steel.

Properties of Cobalt-Nickel-Chromium Alloys made by Powder Metallurgy

G. J. COMSTOCK and J. D. SHAW: 'Alloy Powder Products from Fully Alloyed Powders.' *Physics of Powder Metallurgy*, pp. 372-86; disc., p. 387. Published by McGraw Hill Book Co., 1951.
Metallurgical Abstracts 1952, vol. 20, Sept., p. 28.

Stress-to-rupture tests at 815°C., on bars of cobalt-nickel-chromium alloy pressed from atomized powders, indicate that best results are obtained on compacts sintered for two hours at 1385°C. and hot-coined at 1300°C. It is claimed that the use of pre-alloyed powders makes possible shorter homogenization treatments, and that small amounts of refractory constituents can be incorporated.

Polarographic Determination of Titanium in Nickel-containing Materials

R. P. GRAHAM, A. HITCHEN and J. A. MAXWELL: 'The Polarographic Determination of Titanium in Steels and Nickel-base Alloys.' *Canad. Jnl. Chemistry*, 1952, vol. 30, Sept., pp. 661-7.

Titanium in steels and nickel-base alloys can conveniently be determined polarographically after electrolysis of a solution of the material in a mercury-cathode cell. A well-formed wave, the height of which is directly proportional to the concentration of titanium in the solution, is recorded, using a supporting electrolyte which is 1·0 *M* in tartaric acid, 0·5 *M* in sulphuric acid, and 1·2 *M* in ammonium sulphate. The method gives good precision, and yields values in excellent agreement with those found by umpire methods.

The authors have found this procedure suitable for use on alloys of widely differing composition. In the samples studied in this research, the iron content ranged from less than 1 to more than 99 per cent., the nickel from less than 0·1 to more than 70 per cent., the chromium from less than 0·1 to 20 per cent., the copper from 0·02 to almost 30 per cent., the manganese from 0·2 to over 2 per cent., and the aluminium from 0·03 to over 1 per cent. Typical examples cited, with comparative figures for analysis by umpire methods, include Inconel 'W', Nimonic 75 and 80, Monel, 18-8 steel and open-hearth steel. Type 321 (titanium-stabilized steel) has been successfully analyzed by this procedure, and it has proved suitable for use on a wide variety of rocks and minerals.

Stainless Steels: Fundamental Causes of Corrosion-Resisting Qualities

I. D. G. BERWICK and U. R. EVANS: 'The Cause of the Chemical Resistance of Stainless Steel.' *Jnl. Applied Chemistry*, 1952, vol. 2, Oct., pp. 576-90.

In the introduction the authors review the three theories which have been advanced to account for the inherent chemical resistance of stainless steels. They then report, in considerable detail, experiments (on three chromium-nickel steels of varying composition) designed to test the validity of the theories. The criteria applied were: (1) the influence, on the steels, of anodic and cathodic treatment; (2) their corrosion rates and potentials in aerated and de-aerated acid; (3) times of activation on replacing oxygen by inert gas; (4) times of passivation on replacing inert gas by oxygen; and (5) effect of connexion of the steels with an external aerated cathode.

The findings were as follows:—

Corrosion of stainless steel by dilute sulphuric acid is accelerated by anodic treatment (when the chromium enters the solution in the sexivalent state) or by cathodic treatment (when it enters as tervalent ions).

In acid containing oxygen the corrosion is negligible and the potential positive: in acid freed from oxygen with hydrogen, nitrogen or argon, corrosion is relatively rapid, and the potential is negative.

After short exposure to oxygen-containing acid the replacement of oxygen by another gas produces activity. The time required for the change increases as the preliminary exposure to oxygen is prolonged: if this exceeds a certain critical period passivity persists for long periods after the oxygen has been removed.

The time needed for active stainless steel to become passive depends on the amount of oxygen introduced: below a certain concentration it never becomes passive, whereas above it the reciprocal of the time needed is a rectilinear function of the oxygen added. The relation can be interpreted by the view that an oxide film is formed according to the logarithmic law.

The attack on stainless steel in 20 per cent. sulphuric acid is increased by junction to carbon over which oxygen is passed: the direction of the current generated shows that the stainless steel is being drained of electrons which, according to the electron theory, should render it passive.

The observations made cannot easily be reconciled with the view that the resistance of stainless steel is due to a film of oxygen physically adsorbed on the surface by van der Waals' forces, and it is equally difficult to explain the results by the electron-transfer theory. Neither theory explains the critical quantity of oxygen below which passivity never occurs, and neither is capable of interpreting the quantitative relationship between oxygen addition and time of passivation. All the observations made can, however, be satisfactorily explained by assuming the growth of an oxide film of sensible thickness.

Sulphide Stress-Corrosion: N.A.C.E. Symposium

'Symposium on Sulphide Stress-Corrosion.'
Corrosion, 1952, vol. 8, Oct., pp. 326-60.
(Reprints available as N.A.C.E. Publication 52-3, from N.A.C.E., Central Office, M. and M. Building, Houston 2, Texas; price $1 per single copy; 5 or more copies to one address 50 c. per copy.)

The papers presented (see next page) include an introductory paper reprinted from *Canadian Mining and Metallurgical Bulletin*, and four papers presented at the Oil and Gas Industry Symposium on Sulphide

Stress Corrosion, held in March 1952, during the 8th Annual Conference of the National Association of Corrosion Engineers.

L. W. VOLLMER: 'Hydrogen Sulphide Corrosion Cracking of Steel,' pp. 326-32.

Abstracted from original source, *Canad. Mining and Metallurgical Bull.*, 1952, No. 478, pp. 103-9: see *Nickel Bulletin*, 1952, vol. 25, No. 5, p. 137.

C. N. BOWERS, W. J. McGUIRE and A. E. WIEHE: 'Stress Corrosion Cracking of Steel under Sulphide Conditions,' pp. 333-43.

Rapid failures of tubing in a sour condensate well led to extensive investigation of cause of failure and possible means of prevention. An account is given of laboratory stress-corrosion tests in tap water saturated with hydrogen sulphide and carbon dioxide at atmospheric conditions. Tests were made on 9 and 5 per cent. nickel steels (with and without small additions of chromium or molybdenum); A.P.I. low-manganese steels; precipitation-hardening nickel-chromium stainless steel of the S.A.E. 322 grade; two straight-chromium steels; Monel; K Monel; Inconel. In the case of some of the nickel-alloy steels tests were also made on specimens heat-treated to various hardness levels and pre-stressed prior to stress-corrosion exposure. Results of laboratory tests are correlated with field-service data on tubing of some of the steels.

The following are the main conclusions drawn:—

Tubing steels of the standard type (low-manganese) are at least the equal of the other low-alloy steels under the conditions of loading and environment used. The sensitivity of steel to failure in hydrogen-sulphide environments results primarily from the presence of martensite in the structure, particularly when present as a network. Although plastic deformation is not essential to failure of susceptible steels, in such steels failure is accelerated as the degree of deformation is increased. Plastic deformation of the degree used in this investigation does not affect steels free from martensite. Hardness alone, as ordinarily measured, is not a precise criterion of susceptibility to failure: other mechanical properties are also significant. Susceptibility to failure may be retarded or prevented by any change in composition or treatment which eliminates or sufficiently modifies the martensitic network.

J. P. FRASER and R. S. TRESEDER: 'Cracking of High-Strength Steels in Hydrogen Sulphide Solutions,' pp. 342-50.

This paper reports in detail laboratory investigations made by Shell Development Company, using test apparatus permitting evaluation of the influence of the various factors (environment, metallurgical, and mechanical) involved in sulphide corrosion-cracking. The materials tested were 9 per cent. nickel steel; 5, 7, 9 and 12 per cent. chromium steels; nickel-chromium-molybdenum steel of the S.A.E. 4340 type; N-80 and J. 55 (A.P.I. low-manganese types); 5 per cent. nickel steel. Some supplementary tests were carried out on more-highly-alloyed materials which could possibly be considered for wellhead fittings: this group included austenitic stainless steels, Monel, K Monel, and Stellites Nos. 1 and 6. The value of plastic and metallic coatings is also considered.

Tests in various solutions, and under conditions of varying severity, showed that all the high-strength low-alloy steels tested are susceptible to sulphide corrosion-cracking. The susceptibility of a given material is a function of its mechanical properties, microstructural characteristics, and alloy content. In general, high hardness is associated with high susceptibility to sulphide corrosion-cracking, but at a given hardness a quenched-and-tempered microstructure is markedly less susceptible than a normalized one.

Increased organic acidity favours sulphide corrosion-cracking, and chloride ion increases the severity of the environment towards chromium steels. There is found to be greater probability of failure at low than at high temperatures. Increased stress, whether from applied load, stress raisers, or cold bending, increases probability of failure of any given material in conditions favourable to sulphide corrosion-cracking. Treatment which lowers internal stress will therefore lessen susceptibility to failure.

Of the ordinary tubing and wellhead materials, specimens of J.55 (carbon 0·40, manganese 0·72, per cent.) and a soft cast 12 per cent. chromium steel were found to be completely resistant to cracking. A sample of N-80 (manganese-molybdenum) steel was borderline in susceptibility. The austenitic stainless steels, Monel, K Monel, and the Stellite alloys were resistant, but precipitation-hardening austenitic and chromium martensitic grades of stainless steel proved susceptible. Coatings tested did not provide reliable protection in sulphide conditions.

Based on laboratory test data, a mechanism of sulphide corrosion-cracking is suggested.

NAT. ASSOCN. CORROSION ENGINEERS, TECHNICAL PRACTICES COMMITTEE 1-G: 'Field Experience with Cracking of High-Strength Steels in Sour Gas and Oil Wells,' pp. 351-4.

This report is based on the accumulated field experience of several oil companies, with regard to corrosion-cracking of oil-well tubular goods and wellhead fittings. The effect has been observed mainly with high-strength steels in sour gas-condensate wells. Individual cases recorded in this report (on various types of steel, including 5 and 9 per cent. nickel) confirm that sulphide corrosion-cracking is associated with materials of high hardness, and that the effects may vary from one well to another, due to variation in producing conditions. Some remedial methods are suggested, e.g., use of materials with lowest tensile strengths compatible with mechanical requirements; design of tubing string to ensure lowest possible unit stresses; use of protective coatings, and of corrosion inhibitors. In the case of small items of equipment the problem of sulphide corrosion-cracking has been met by use of Type 316 stainless steel or K Monel.

F. A. PRANGE: 'Hydrogen Embrittlement Tests on Various Steels,' pp. 355-7.

Cathodic embrittlement tests were made on some materials having properties recommending their use in deep corrosive wells. The steels tested included 3½, 5 and 9 per cent. nickel steels, 9 and 12 per cent. chromium steels, 5 per cent. nickel steels containing chromium or molybdenum, and a 9 per cent. nickel steel with titanium addition.

In general, composition appears to affect resistance to cracking only very slightly. The limiting hardness for crack-free operation under severe hydrogen-embrittlement conditions is placed at about Rockwell C-20. In 9 per cent. nickel steel containing titanium, which showed the highest resistance of all the materials tested, only very slight cracking was observed at a hardness of Rockwell C-24.

Stress-Corrosion Tests on Plated Bronze

C. H. HANNON: 'A Practical Evaluation of Metallic Coatings as Affecting Sensitivity to Stress-Corrosion Failure.' *Metal Finishing*, 1952, vol. 50, Oct., pp. 65-6, 71.

The article reports an investigation carried out in the laboratories of the General Electric Company, Pittsfield, Mass., following failures of electrical bushing terminal bolts in distribution transformer terminal clamps. The majority of the tests were made on eyebolts of an alloy containing copper 91, aluminium 7, silicon 2, per cent. Exposure to mercurous nitrate and to ammonia was made on specimens carrying the following types of coating, with the results shown:—

Mercurous Nitrate		Ammonia	
Ni	Failed	Ni	Failed
Cu+Ni+Cr	,,		
Cu+Ni+Sn(1)	Passed	Sn(1)	Passed
Cu+Sn	,,		
Ni+Sn(1)	,,		
Sn(2)	,,	Sn(2)	Failed
Sn(3)	Failed	Sn(3)	,,
Ag	,,	Ag	,,
Cu+Ag	,,		
Cd	,,	Cd	,,

(1) Tin coating flowed.
(2) Tin coating as electroplated.
(3) Tin coating diffused at 700°C.

(1) Tin coating melted.
(2) Tin coating as electroplated.
(3) Tin coating diffused at 700°C.

The results indicate that under the mercurous-nitrate test the element essential in the coating is tin, either as electroplated or in the state of a flowed coating, and that its effectiveness is solely chemical in nature. A reaction between the tin and the mercurous-nitrate solution, which is sacrificial so far as the tin is concerned, progresses during immersion, and serves to weaken the activity of the mercury-salt solution. As long as metallic tin remains, a sponge-like product continues to form, which prevents deposition of mercury on the base-metal surface.

The results of the tests in ammonia are considered to be more significant in rating the effectiveness of the various coatings. In this case tin, as electroplated, does not provide immunity to stress-corrosion cracking. The fact that a beneficial effect is secured by a flowed-tin coating suggests that a chemically inactive and impervious coating is the logical means of preventing such failures. Continuity of film and absence of porosity are obviously of major importance.

Atmospheric Corrosion-Resistance of Low-Alloy Nickel-containing Steels

H. R. COPSON: 'Atmospheric Corrosion of Low-Alloy Steels.'* Reprint of paper to Amer. Soc. Testing Materials, June, 1952; issued by International Nickel Co., Inc.

For abstract see *Nickel Bulletin*, 1952, vol. 25, Nos. 8-9, pp. 222-3.

Nickel-containing Materials in Chemical Engineering: Annual Review

H. O. TEEPLE: 'Nickel and Nickel-base Alloys.' *Industrial and Engineering Chemistry*, 1952, vol. 44, Oct., pp. 2325-38.

This paper, which forms part of the 6th Annual Review of Materials of Construction used in Chemical Engineering, comprises a well-documented survey of the major developments of the past year. It is pointed out that although critical supply conditions make it still desirable for the chemical and process industries to conserve nickel as far as is economically possible, much can be done in the chemical-engineering field by optimum utilization of the supplies of nickel which are available. During the past year work has been done on development of new alloys for use in specialized applications, and by improvements of known types. The main features of such progress are recorded (with due reference to original literature), in sections concerned with: compositions of alloys, phase diagrams, etc.; properties of nickel-containing alloys, including high-temperature properties; fabrication methods (welding, mechanical forming); plating with nickel; applications (in the high-temperature field, in the petroleum industry and other chemical-engineering equipment). The review is supported by a *bibliography* of 293 references.

W. A. LUCE: 'Stainless Steels and Other Ferrous Alloys,' *ibid.*, pp. 2346-59.

In this field there has been much literature dealing with conservation of critical elements in stainless steels, and many basic papers have been published relating to corrosion- and heat-resistance, physical and mechanical properties, welding, and fabrication of both the austenitic steels and the straight-chromium grades which are being used in the interests of economy

**Copies of this publication will shortly be available.*

in alloying elements. This review also includes sections dealing with high-silicon irons, iron-nickel alloys (of the types interesting to the chemical engineer), and austenitic manganese steels. The *bibliography* contains 287 references.

Nickel-containing Materials in Contact with Liquid Hydrogen Sulphide

W. O. BICE, F. PRANGE and R. E. WEIS: 'Handling Liquid Hydrogen Sulfide.' *Industrial and Engineering Chemistry*, 1952, vol. 44, Oct., pp. 2497-500.

This article, one of a series describing pilot installations engaged in various types of process, is based on experience of the Phillips Petroleum Company's plant at Borger, Texas, where natural and refinery gases of high sulphur content provide an abundant supply of hydrogen sulphide. The various stages of processing are described in some detail, and a schematic flow diagram of the sulphur-compounds plant is given. Materials of construction used in various units are mentioned. It is noted that in the gas engine-driven compressor in which the hydrogen sulphide is compressed the cylinders are equipped with Ni-Resist linings, Inconel garter springs for the carbon-steel packing, and stainless-steel valve assemblies fitted with Inconel springs.

Aqueous hydrogen sulphide is much more corrosive than the anhydrous sulphide, and it is therefore desirable to design equipment so that any water collecting in the system after shutdowns can be drained. It is noted that embrittlement failures of highly stressed hard steel parts are common in sulphide environments. Among the numerous examples cited, reference is made to trouble experienced with steel garter springs for holding metallic packing and valve springs for reciprocating pumps. These failed rapidly, but replacement by age - hardened Inconel garter springs has resulted in trouble-free service for over five years.

Pickling of Stainless Steels

J. BARY: 'Pickling of Stainless Steels.' *Métallurgie*, 1952, vol. 84, pp. 259-61.

It is pointed out that, due to limitations inherent in the nitric-hydrofluoric acid bath, the hydrofluoric acid-ferric sulphate solution is increasing in popularity. The action of this bath is discussed and some recommendations are made as to percentage composition. *Inter alia*, consideration is given to solutions suitable for pickling work containing welded joints: a bath containing 6-8 per cent. ferric sulphate and 2 per cent. hydrofluoric acid may be used, or, in place of hydrofluoric acid, fluorides, in the presence of a sulphuric acid, may be employed. In such case an appropriate composition for the pickling solution would be calcium fluoride 50 g., sulphuric acid 130 g., ferric sulphate 80 g., water 1000 c.c. It is stated that this bath works well with 18-8-Mo steel, rapidly removing the oxides present along the weld seam, but attacking the metal only slowly. Recommendations are also made with regard to ferric sulphate replenishment of hydrofluoric acid-ferric sulphate baths, to prevent excess ferrous sulphate content arising from high consumption of the ferric salt.

Machining and Finishing of Stainless Steels

'How to Machine and Finish Stainless Steel.' *Machinist*, 1952, vol. 96, Oct. 18, pp. 1693-1708.

American Machinist Special Report No. 315 to the Metalworking Industries.

Practical, highly detailed, recommendations on tools and technique for various machining operations, and on grinding, polishing and buffing procedures.

Examination of Films Formed on Stainless Steels and Other Metals

T. J. NURSE and F. WORMWELL: 'The Isolation and Examination of Films from Metal Surfaces: an Improved Technique.' *Jnl. Applied Chemistry*, 1952, vol. 2, Sept., pp. 550-3.

The paper describes improved technique developed at the Chemical Research Laboratory for removal of oxide films from metal surfaces, with particular reference to the possibility of obtaining larger pieces of film and of facilitating their manipulation. The method involves reinforcement of the film by Formvar (polyvinylformal) resin. Full details of procedure are given.

The usefulness of the method is demonstrated by an account of results obtained in separating oxide films on heated mild steel, films on iron and steel produced by industrial treatments, and the oxide film on 18-8 chromium-nickel steel. Some particular problems involved in removal of films from non-ferrous metals are discussed.

The electron-diffraction pattern of the film from the stainless steel indicated an amorphous structure, but it is considered that further work, using an alternative backing material, is required before final conclusions can be drawn with regard to the constitution of the oxide film. Nickel was not detected in the stripped film, and to confirm the absence of nickel a film from heated sheet nickel was removed and analyzed. Quantitative agreement consistent with the formula of NiO was obtained between the oxygen content of the isolated oxide film as calculated from the nickel determination and as observed from the weight increment of the specimen.

Corrigendum

p. 86 left-hand column line 7
for "weld metal" read "base metal".

Binders bearing the date 195- and suitable for 1952 and 1953 Nickel Bulletins are now available. We shall be pleased to send one free of charge.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

SUBJECT INDEX TO VOLUME 25

The index comprises a consolidated list compiled from the sectional contents lists of the individual issues.

Within the sections normally used (**GENERAL, NICKEL, ELECTRODEPOSITION,** etc.) the items are *broadly classified* in appropriate sub-sections, within which the items are entered *in the order of their appearance in the Bulletin.*

The only exception to this is the grouping of the page numbers of serial items and of items of very closely similar subject matter; also the arrangement in alphabetical order of the items in the **GENERAL** section.

Leading articles and data sheets are listed separately, and are also shown in the appropriate sections. In the sections they are differentiated from abstracts by an asterisk at the beginning of the title.

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